Astronomy and Astrophysics 2018 vol.612

The hypersoft state of Cygnus X-3: A key to jet quenching in X-ray binaries?

Koljonen K., Maccarone T., McCollough M., Gurwell M., Trushkin S., Pooley G., Piano G., Tavani M.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© ESO 2018. Context. Cygnus X-3 is a unique microquasar in the Galaxy hosting a Wolf-Rayet companion orbiting a compact object that most likely is a low-mass black hole. The unique source properties are likely due to the interaction of the compact object with the heavy stellar wind of the companion. Aim. In this paper, we concentrate on a very specific period of time prior to the massive outbursts observed from the source. During this period, Cygnus X-3 is in a so-called hypersoft state, in which the radio and hard X-ray fluxes are found to be at their lowest values (or non-detected), the soft X-ray flux is at its highest values, and sporadic γ-ray emission is observed. We use multiwavelength observations to study the nature of the hypersoft state. Methods. We observed Cygnus X-3 during the hypersoft state with Swift and NuSTAR in X-rays and SMA, AMI-LA, and RATAN-600 in the radio. We also considered X-ray monitoring data from MAXI and γ-ray monitoring data from AGILE and Fermi. Results. We found that the spectra and timing properties of the multiwavelength observations can be explained by a scenario in which the jet production is turned off or highly diminished in the hypersoft state and the missing jet pressure allows the wind to refill the region close to the black hole. The results provide proof of actual jet quenching in soft states of X-ray binaries.

http://dx.doi.org/10.1051/0004-6361/201732284

Keywords

Accretion, accretion disks, Binaries: close, Stars: individual: Cyg X-3, Stars: winds, outflows, X-rays: binaries

References

[1] Abdo A. A et al. (Fermi LAT Collaboration), 2009, Science, 326, 1512
[2] Abdo, A. A., Ackermann, M., Ajello, M., et al. 2010, ApJ, 723, 649
[3] Axelsson, M., Larsson, S., & Hjalmarsdotter, L. 2009, MNRAS, 394, 1544
[4] Bachetti, M. 2015, MaLTPyNT: Quick look timing analysis for NuSTAR data, Astrophysics Source Code Library
[5] Bachetti, M., Harrison, F. A., Cook, R., et al. 2015, ApJ, 800, 109
[6] Barbiellini, G., Fedel, G., Liello, F., et al. 2002, Nucl. Instr. Meth. Phys. Res. B, 490, 146
[7] Beckmann, V., Soldi, S., Bélanger, G., et al. 2007, A&A, 473, 903
[8] Bodaghee, A., Tomsick, J. A., Pottschmidt, K., et al. 2013, ApJ, 775, 98
[9] Bulgarelli, A., Tavani, M., Chen, A. W., et al. 2012, A&A, 538, A63
[10] Burrows, D. N., Hill, J. E., Nousek, J. A., et al. 2005, Space Sci. Rev., 120, 165

[11] Cadolle Bel, M., Ribó, M., Rodriguez, J., et al. 2007, ApJ, 659, 549
[12] Cheung, C. C., & Loh, A. 2016, ATel, 9502
[13] Cooke, R., Kuncic, Z., Sharp, R., & Bland-Hawthorn, J. 2007, ApJ, 667, L163
[14] Corbel, S., Dubus, G., Tomsick, J. A., et al. 2012, MNRAS, 421, 2947
[15] De Becker, M., & Raucq, F. 2013, A&A, 558, A28
[16] de la Cita, V. M., del Palacio, S., Bosch-Ramon, V., et al. 2017, A&A, 604, A39
[17] Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
[18] Drappeau, S., Malzac, J., Coriat, M., et al. 2017, MNRAS, 466, 4272
[19] Dubus, G., Cerutti, B., & Henri, G. 2010, MNRAS, 404, L55
[20] Earnshaw, H. M., & Roberts, T. P. 2017, MNRAS, 467, 2690
[21] Egron, E., Pellizzoni, A., Giroletti, M., et al. 2017, MNRAS, 471, 2703
[22] Fabrika, S. 2004, Astrophys. Space Phys. Rev., 12, 1
[23] Fender, R., Corbel, S., Tzioumis, T., et al. 1999, ApJ, 519, L165
[24] Fender, R. P., & Hendry, M. A. 2000, MNRAS, 317, 1
[25] Fender, R. P., Bell Burnell, S. J., Garrington, S. T., Spencer, R. E., & Pooley, G. G. 1995, MNRAS, 274, 633
[26] Fender, R. P., Bell Burnell, S. J., Waltman, E. B., et al. 1997, MNRAS, 288, 849
[27] Froning, C. S., Maccarone, T. J., France, K., et al. 2014, ApJ, 780, 48
[28] Gallo, E., Fender, R., Kaiser, C., et al. 2005, Nature, 436, 819
[29] Gehrels, N., Chincarini, G., Giommi, P., et al. 2004, ApJ, 611, 1005
[30] Gilfanov, M., & Arefiev, V. 2005, ArXiv Astrophysics [arXiv: astro-ph/0501215]
[31] Gregory, P. C., & Seaquist, E. R. 1974, ApJ, 194, 715
[32] Harrison, F. A., Craig, W. W., Christensen, F. E., et al. 2013, ApJ, 770, 103
[33] Hjalmarsdotter, L., Zdziarski, A. A., Larsson, S., et al. 2008, MNRAS, 384, 278
[34] Hornby, J. M., & refauWilliams, P. J. S. 1966, MNRAS, 131, 237
[35] Kaiser, C. R., Sunyaev, R., & Spruit, H. C. 2000, A&A, 356, 975
[36] Kallman, T. R., Palmeri, P., Bautista, M. A., Mendoza, C., & Krolik, J. H. 2004, ApJS, 155, 675
[37] Kellermann, K. I., & Pauliny-Toth, I. I. K. 1981, ARA&A, 19, 373
[38] Koljonen, K. I. I., & Maccarone, T. J. 2017, MNRAS, 472, 2181
[39] Koljonen, K. I. I., Hannikainen, D. C., McCollough, M. L., Pooley, G. G., & Trushkin, S. A. 2010, MNRAS, 406, 307
[40] Koljonen, K. I. I., Hannikainen, D. C., & McCollough, M. L. 2011, MNRAS, 416, L84
[41] Koljonen, K. I. I., McCollough, M. L., Hannikainen, D. C., & Droulans, R. 2013, MNRAS, 429, 1173
[42] Koljonen, K. I. I., Russell, D. M., Fernández-Ontiveros, J. A., et al. 2015, ApJ, 814, 139
[43] Krimm, H. A., Holland, S. T., Corbet, R. H. D., et al. 2013, ApJS, 209, 14
[44] Kylafis, N. D., & Klimis, G. S. 1987, ApJ, 323, 678
[45] Leitherer, C., & Robert, C. 1991, ApJ, 377, 629
[46] Lindfors, E. J., Türler, M., Hannikainen, D. C., et al. 2007, A&A, 473, 923
[47] Loh, A., & Corbel, S. 2017a, ATel, 10109
[48] Loh, A., & Corbel, S. 2017b, ATel, 10243
[49] Maccarone, T. J. 2005, MNRAS, 360, L68
[50] Maccarone, T. J., & Coppi, P. S. 2003, MNRAS, 338, 189
[51] Marscher, A. P., & Gear, W. K. 1985, ApJ, 298, 114
[52] Marti, J., Paredes, J. M., & Estalella, R. 1992, A&A, 258, 309
[53] Matsuoka, M., Kawasaki, K., Ueno, S., et al. 2009, PASJ, 61, 999
[54] McCollough, M., Koljonen, K., Hannikainen, D., et al. 2010, in The Restless Gamma-ray Universe (INTEGRAL 2010), Eighth Integral Workshop, 25
[55] McCollough, M. L., Robinson, C. R., Zhang, S. N., et al. 1999, ApJ, 517, 951
[56] McCollough, M. L., Corrales, L., & Dunham, M. M. 2016, ApJ, 830, L36
[57] Meier, D. L. 2001, ApJ, 548, L9
[58] Migliari, S., Tomsick, J. A., Markoff, S., et al. 2007, ApJ, 670, 610
[59] Mihara, T., Nakajima, M., Sugizaki, M., et al. 2011, PASJ, 63, S623
[60] Miller, J. M., Raymond, J., Reynolds, C. S., et al. 2008, ApJ, 680, 1359

[61] Miller-Jones, J. C. A., Blundell, K. M., Rupen, M. P., et al. 2004, ApJ, 600, 368
[62] Miller-Jones, J. C. A., Sakari, C. M., Dhawan, V., et al. 2009, in 8th Int. e-VLBI Workshop, 17
[63] Mioduszewski, A. J., Rupen, M. P., Hjellming, R. M., Pooley, G. G., & Waltman, E. B. 2001, ApJ, 553, 766
[64] Miyamoto, S., Kitamoto, S., Hayashida, K., & Egoshi, W. 1995, ApJ, 442, L13
[65] Narayan, R. & McClintock, J. E. 2012, MNRAS, 419, L69
[66] Neilsen, J., & Homan, J. 2012, ApJ, 750, 27
[67] Neilsen, J., & Lee, J. C. 2009, Nature, 458, 481
[68] Neilsen, J., Rahoui, F., Homan, J., & Buxton, M. 2016, ApJ, 822, 20
[69] Ogley, R. N., Bell Burnell, S. J., Spencer, R. E., et al. 2001, MNRAS, 326, 349
[70] Orosz, J. A., & Bailyn, C. D. 1997, ApJ, 477, 876
[71] Paerels, F., Cottam, J., Sako, M., et al. 2000, ApJ, 533, L135
[72] Pakull, M. W., Soria, R., & Motch, C. 2010, Nature, 466, 209
[73] Piano, G., Tavani, M., Vittorini, V., et al. 2012, A&A, 545, A110
[74] Piano, G., Tavani, M., Bulgarelli, A., et al. 2016, ATel, 9429
[75] Piano, G., Tavani, M., Munar-Adrover, P., et al. 2017a, ATel, 10138
[76] Piano, G., Tavani, M., Verrecchia, F., et al. 2017b, ATel, 10179
[77] Ponti, G., Fender, R. P., Begelman, M. C., et al. 2012, MNRAS, 422, L11
[78] Prest, M., Barbiellini, G., Bordignon, G., et al. 2003, Nucl. Instrum. Methods Phys. Res. A, 501, 280
[79] Rees, M. J. 1978, MNRAS, 184, 61P
[80] Romero, G. E., Torres, D. F., Kaufman Bernadó, M. M., & Mirabel, I. F. 2003, A&A, 410, L1
[81] Rushton, A. P., Shaw, A. W., Fender, R. P., et al. 2016, MNRAS, 463, 628
[82] Russell, D. M., Fender, R. P., Gallo, E., & Kaiser, C. R. 2007, MNRAS, 376, 1341
[83] Russell, D. M., Gallo, E., & Fender, R. P. 2013, MNRAS, 431, 405
[84] Russell, D. M., Miller-Jones, J. C. A., Maccarone, T. J., et al. 2011, ApJ, 739, L19
[85] Sahakyan, N., Piano, G., & Tavani, M. 2014, ApJ, 780, 29
[86] Savolainen, P. 2012, in X-ray Binaries. Celebrating 50 Years Since the Discovery of Sco X-1, 52
[87] Sell, P. H., Heinz, S., Richards, E., et al. 2015, MNRAS, 446, 3579
[88] Shaw, A. W., Gandhi, P., Altamirano, D., et al. 2016, MNRAS, 458, 1636
[89] Shidatsu, M., Done, C., & Ueda, Y. 2016, ApJ, 823, 159
[90] Sikora, M., Begelman, M. C., Madejski, G. M., & Lasota, J.-P. 2005, ApJ, 625, 72
[91] Simon, M. 1969, ApJ, 156, 341
[92] Sincell, M. W., & Krolik, J. H. 1994, ApJ, 430, 550
[93] Smale, A. P., Mushotzky, R. F., Schlegel, E. M., et al. 1993, ApJ, 418, 894
[94] Smith, D. M., Heindl, W. A., & Swank, J. H. 2002, ApJ, 569, 362
[95] Steiner, J. F., Narayan, R., McClintock, J. E., & Ebisawa, K. 2009, PASP, 121, 1279
[96] Szostek, A. & Zdziarski, A. A. 2005, in X-ray Diagnostics of Astrophysical Plasmas: Theory, Experiment, and Observation, ed. R. Smith, AIP Conf. Ser., 774, 341
[97] Szostek, A., & Zdziarski, A. A. 2008, MNRAS, 386, 593
[98] Szostek, A., Zdziarski, A. A., & McCollough, M. L. 2008, MNRAS, 388, 1001
[99] Tavani, M., Barbiellini, G., Argan, A., et al. 2009a, A&A, 502, 995
[100] Tavani, M., Bulgarelli, A., Piano, G., et al. 2009b, Nature, 462, 620
[101] Trushkin, S., McCollough, M., Nizhelskij, N., & Tsybulev, P. 2017a, Galaxies, 5, 86
[102] Trushkin, S. A., Nizhelskij, N. A., Tsybulev, P. G., & Zhekanis, G. V. 2017b, in Stars: From Collapse to Collapse, eds. Y. Y. Balega, D. O. Kudryavtsev, I. I. Romanyuk, & I. A. Yakunin, in ASP Conf. Ser., 510, 492
[103] Tudose, V., Fender, R. P., Garrett, M. A., et al. 2007, MNRAS, 375, L11
[104] Uttley, P., & Klein-Wolt, M. 2015, MNRAS, 451, 475
[105] Vadawale, S. V., Rao, A. R., Naik, S., et al. 2003, ApJ, 597, 1023
[106] van der Laan, H. 1966, Nature, 211, 1131
[107] van Kerkwijk, M. H., Charles, P. A., Geballe, T. R., et al. 1992, Nature, 355, 703
[108] Vaughan, S., Edelson, R., Warwick, R. S., & Uttley, P. 2003, MNRAS, 345, 1271
[109] Vilhu, O., Hakala, P., Hannikainen, D. C., McCollough, M., & Koljonen, K. 2009, A&A, 501, 679
[110] Waltman, E. B., Fiedler, R. L., Johnston, K. J., & Ghigo, F. D. 1994, AJ, 108, 179

[111] Waltman, E. B., Foster, R. S., Pooley, G. G., Fender, R. P., & Ghigo, F. D. 1996, AJ, 112, 2690
[112] Williams, P. K. G., Tomsick, J. A., Bodaghee, A., et al. 2011, ApJ, 733, L20
[113] Wright, A. E., & Barlow, M. J. 1975, MNRAS, 170, 41
[114] Yoon, D., & Heinz, S. 2015, ApJ, 801, 55
[115] Yoon, D., Zdziarski, A. A., & Heinz, S. 2016, MNRAS, 456, 3638
[116] Zdziarski, A. A., Misra, R., & Gierliński, M. 2010, MNRAS, 402, 767
[117] Zdziarski, A. A., Sikora, M., Dubus, G., et al. 2012, MNRAS, 421, 2956
[118] Zwart, J. T. L., Barker, R. W., Biddulph, P., et al. 2008, MNRAS, 391, 1545